Leonardo da Vinci as mural painter:
some observations on his materials and working methods

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Introduction

In contrast to the enormous body of art historical research published on Leonardo da Vinci, relatively little information is available regarding his painting materials and working methods. In this paper I hope to touch on some aspects of Leonardo's mural painting technique, and to relate this information to historical precedents including his own treatises.

Analyses of ten paint cross sections removed in 1976 (before the recent restoration), indicate that portions of the *Last Supper* are painted in an oil medium. The presence of tempera and glue were detected as well. The technique of oil on wall appears to have been practised at least a century before Leonardo, particularly in Northern Europe; the technique is mentioned in various treatises that he had access to. A significant feature of the oil technique is the ability to create transparent effects by layering one color upon another. A complex stratification of pigments is found in the *Last Supper* and parallels Leonardo's observations in his *Treatise on Painting*.

Examination of the figures of Beatrice d'Este and Francesco on the Montorfano fresco in Santa Maria delle Grazie indicates that they were reworked with a sharp instrument and colored in a secco techinique. The reproduction of these incised lines may help establish the authorship of the altered forms, a reworking which has been traditionally attributed to Leonardo.

Lists of materials purchased for the *Battle of Anghiari* indicate that it too was to have been an oil mural. Samples of pigments suspended in an oil medium, recently discovered beneath frescoes by Giorgio Vasari, may indicate the presence of traces of the Leonardo mural. The Soprintendente per i Beni Artistici e Storici of Florence, Professor Umberto Baldini, is currently investigating the situation.

It is my hope that restorers will continue to contribute to Leonardo scholarship, as the history of his painting materials is an area that clearly requires closer study.

Leonardo da Vinci and the Tradition of Oil Mural Painting

At least two major technological innovations in artists' materials in Italy were well under way by the time Leonardo began his painting career: the gradual substitution of drying oils for egg tempera as a medium for pigments, and a shift from wooden panel to woven linen as a painting support [1].

The second half of the 15th century was a period of extensive experimentation with artists materials in Italy. Leonardo was certainly one of the great innovators of his time, yet an examination of his painting materials indicates that he followed many traditions of his day. For example, he seems to have preferred the wooden panel rather than canvas for a painting support. Although he described a method for preparing canvas, his paintings that have survived to this day are on panel [2].

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[1] A complete survey of the literature on these two subjects is not within the scope of this paper. Of particular recent interest, however, see «Methods Used for the Identification of Binding Media in Italian Paintings of the 15th and 16th Centuries», by M. Johnson, and E. Packard, *Studies in Conservation*, 16 (1971), 145-164; J.A. Van de Graaf, «Development of Oil Paint and the Use of Metal Plates as a Support», in *Conservation and Restoration of Pictorial Art*, ed. by Norman Brommelle and Perry Smith, IIC London, 1976, 34-53; M.C. Gay, Annales Laboratoire de Recherche des Musées de France, 1 (1970), 8-24; regarding the transition from panel to canvas, see D. Bosshard, «Tüchleinmalerei-ein billige Ersatztechnik?», *Zeitschrift Für Kunstgeschichte*, Munich, 1982, and K. Nicolaus, *Handbuch der Gemäldekunde*.

[2] See, for example the section on «Esecuzione», in *Leonardo pittore*, Milano, Rizzoli, 1967, 82-110.

According to Cennino Cennini, the lessons of panel painting prepare the artist for the rigors of mural painting:

> And bear this well in mind, that anyone who learns to work on the wall first, and then on panel, will not get such perfect mastery by his bargain as one who starts learning on panel first, and then on the wall [3].

Although research remains to be conducted regarding Leonardo's use of media in his panel paintings, it is clear that he experimented with various paint media for his wall paintings. Documentary evidence and recent examination of pigment samples indicate that the *Last Supper* and the *Battle of Anghiari* murals may have been painted in a predominantly oil medium. The use of oil on wall was not common in Italy at that time, although it appears that European artists had been working in that method for many years before the *Last Supper* was painted.

The history of the use of oil as a painting medium in Italy is a subject that is still not clearly understood. It does appear that oil was used as a vehicle for dry pigments for glass painting and on metal leaf in Medieval times. There is a recipe for an oil varnish mixed with saffron and orpiment to give tin leaf the aspect of gold in an 8th century Lucca manuscript [4]. Similar versions of this method appear in the 11th century (Theophilus) [5], and in the 13th century (Eraclius) [6]. Recipes exist in Italy from the late 14th century regarding procedures for painting on glass with varnish or linseed oil [7]. Recently developed techniques of examining paint strata have shown a limited use of oil within tempera panels from the first half of the 14th century, with oil gradually replacing egg tempera by the first half of the 17th century [8].

Contemporaneous to its use over gold leaf and on glass, oil was used in Europe on columns to imitate stone or marble [9]. The glossy surface characteristics of oil when mixed with a compact plaster reflect light much in the same way as marble. Eraclius gives the following recipe for preparing a column for oil painting:

> If you wish to paint on a column, or on a stone slab, first dry it perfectly in the sun, or by means of fire. Then take white lead, and grind it very finely with oil on a piece of marble. Spread the white with a broad brush two or three times over the column, which is already quite smooth and even, without any cavities. Afterwards prime with stiff white, applying it with your hand or with a brush, and let it remain awhile. When it is tolerably dry, pass your hand with some pressure over the surface, drawing you hand towards you, and continue to do this till the surface is as smooth as glass. You may then paint upon it with any colors mixed with oil. If you wish to imitate the veins of marble on a general tint (brown, black, or any other color), you can give the appearance when the ground so prepared is dry. Afterwards varnish in the sun [10].

By the time Cennino Cennini wrote his *Treatise on Painting* in the beginning of the 15th century, German artists were actively painting on wall with an oil medium [11]. Oil was not just used for the immitation of marble, but for figurative compositions as well. The reasons for this evolution in technique are varied, but it seems that the Northern artists believed that the oil would provide a barrier against dampness within walls, and hence increase the painting's longevity [12]. Cennini himself was familiar with oil painting media as he gives detailed instructions for refining oil in order to gain proper drying properties [13]. In addition, he devotes two chapters of his treatise to oil painting on wall, and gives the following details:

> Plaster the wall the way you do for fresco; except that where you do the plastering little by little, here you are to plaster the whole job at once. Then draw your scene with charcoal, and fix it

[3] «E tieni bene a mente, che chi imparasse allavorare prima in muro e poi in tavola, non viene chosi perfetto maestro nell'achato (chi) perviene a imparare prima in tavola e poi in muro» (Cennino d'Andrea Cennini, *Il Libro dell'Arte*, ed. by D.V. Thompson, New Haven, 1932, vol. I, 62). According to P. McMahon, *Treatise on Painting* (Princeton, 1956), Leonardo was familiar with a number of technical treatises, either directly or indirectly, including that of Cennino Cennini, Leon Battista Alberti, Averlino Filarete, and Piero della Francesca. McMahon relates: «We cannot be sure that he saw Cennini's (treatise) in the original version, but it is certain that he was familiar with Filarete's big treatise, which made extensive use, albeit without acknowledgement, of Cennini's book on painting. Leonardo made use of the Filarete book, which existed in a large and splendidly decorated manuscript in the Sforza library, for his own architectural studies. Therefore he must have known the sections dealing with the art of drawing and painting also, which are largely derived from Cennini» (McMahon, 1956, vol. I, XXV).

[4] *Compositiones ad Tingenda*, Bibl. Capitolare di Lucca, ms 490 (Published by Muratori, L.A., *Antiquitates Italica*, II, 364-387: Dissertatio XXIV).

[5] Theophilus, *Schedula Diversarus Artium*, ed. Theobald, 1933.

[6] Heraclius, *De Coloribus et Artibus Romanorum*, ed. Ilg.

[7] A. da Pisa, *Secreti per Lavorare li Vetri, Secondo la Dottrina di Maestro Antonio da Pisa Singolare in Tal Arte*, Archivio Comunale, Assisi, MS 692 (published by Buck, R., *Rep. für Kunstwissenschaft*, XXV, 1902, 240 et seq.).

[8] M. Johnson, and E. Packard, 1971, 156.

[9] C.L. Eastlake, *Methods and Materials of Painting of the Great Schools and Masters*, New York, 1960, vol. I, 58-59. Eastlake refers to Eraclius' description of oil used on walls at Ely and Westminster.

[10] Eastlake, 1960, vol. I, 34. The lead white was mixed with the linseed oil for two major reasons. The addition of lead accelerates the drying rate of oil. Secondly, a ground prepared with lead white and linseed oil reduces a wall's absorption of subsequent oil paint layers.

[11] Cennini, 56: «ti voglio insegnare allavorare d'olio in muro o in tavola, che l'usano molto i Tedeschi».

[12] Eastlake, 1960, vol. II, 62.

[13] Cennini, 58-59.

[14] Cennini, 57-58.

> either with ink or with tempered verdaccio. Then take a little well-diluted size. A still better tempera is the whole egg beaten in a porringer with fig-tree latex; and pour a goblet of clear water over this egg. Then, either with a sponge or with the soft, rather blunt brush, apply one coat of it all over the ground which you have to execute; and let it dry for at least one day... Go back to working up or grinding, color by color, as you did for work in fresco; except that where you worked them up with water you now work them up with this oil [14].

Cennini's recipe differs considerably from that of Eraclius as glue is applied to the wall in the place of lead white. The composition is then underpainted on the wall in tempera as though it were a sinopia for a fresco.

Leon Battista Alberti wrote in *De Re Aedificatoria* of an oil technique on wall that he considered both new and resistant to decay:

> It was recently discovered that, mixed with linseed oil, colors applied to wall acquire an unlimited resistance to all effects of the atmosphere as long as the wall is dry and without any trace of humidity [15].

Antonio Filarete wrote in his treatise on painting (1464) of a method of painting on wall similar to that of Eraclius. Filarete specified that once the plaster is dry, a layer of lead white ground in linseed oil is applied to the wall. The oil mural is then completed on this surface [16].

Examples of oil murals from the first half of the 15th century exist in Northern Europe [17]. And according to Vasari, Italian artists were working in this new technique soon after. He claims that Domenico Veneziano, Andrea Castagno and the Pollaiuolo brothers were among the first to experiment with oil murals in Italy [18].

Vasari relates that Raphael ordered that one of the walls be prepared for oil in the Sala di Costantino in the Vatican [19]. Giulio Romano and others completed the decoration of this room after Raphael's death, and at least two sections, depicting Justice and Forbearance (ca. 1520) are painted in oil [20]. Vasari describes in detail the oil technique used by Sebastiano del Piombo in his *Flagellation of Christ* mural of 1516-21 in the Borgherini Chapel of S. Pietro in Montorio, Rome (fig. 1):

> Thus his Christ at the Column in S. Pietro has never changed, possessing the same brilliancy of color as on the first day. He used every care, employing a rich lime arriccio mixed with mastic and Greek pitch, which he melted together on the fire and laid on the wall, smoothing it over with a red hot plaster trowel, so that his things have stood the damp and kept their color. And with the same mixture he painted on peperigni, stone, marble, porphyry, and similar materials, on which paintings last a very long time [21].

Vasari relates that Sebastiano was so enthusiastic about the oil mural technique that he attempted to persuade Michelangelo to work in the new method:

> [Sebastiano] was a great friend of Michelangelo. But when he had to paint a wall of the Pope's chapel, where Buonarroti's Last Judgement is, some coldness arose between them, for Sebastiano persuaded the Pope to have it done in oils, while Michelangelo did not wish to do it except in fresco. As Michelangelo did not declare himself one way or the other, and the wall was prepared in Sebastiano's fashion, several months passed and nothing was done, but on being approached Michelangelo declared that he would only do it in fresco, and that oil-painting was a woman's art and only fit for lazy well-to-do people like Fra Sebastiano. Accordingly he removed the incrustation made by the friar's direction, and prepared everything in «arriccio» so to work in fresco [22].

Around 1540 Vasari claimed to have begun his own experiments with oil murals [23]. He described two recipes in detail:

> When artists wish to work in oil on the dry wall two methods may be followed: first, if the wall

[15] L.B. Alberti, *De Re Aedificatoria*, Milano, 1966, 504: «Recentemente si è scoperto che, mescolati ad olio di lino, i colori da applicarsi sui muri acquistano una resistenza illimitata contro le intemperie, a condizione che la parete su cui vengono stesi sia asciutta e priva di qualsiasi traccia di umidità».

[16] Quoted by Eastlake, 1960, vol. I, 66: «muro che sia la calcina vuole essere seccha et poi una mano di colore macinato a olio sella biaccha e buona».

[17] See for example P. Cadorin, «Zur Technik und Restaurierung des Basler Otoentanzes», *Kunstmuseum Basel*, 1979; this was brought to my attention by Emil Bosshard, Chief Conservator of the Swiss Institute for Art Research, Zurich. See also the oil mural of St. Christopher in Erfurt Cathedral, reproduced in plate 18 of *La conservation des peintures murales*, Mora and Phillippot, Rome, 1977.

[18] Vasari, *Lives of the Most Eminent Painters*, London, De Vere, 1912, vol. III, 102-103, Vasari describes oil murals that Castagno and Domenico Veneziano painted for the church of Santa Maria Nuova, Florence; p. 239, he describes the Pollaiuolo brother's work in San Miniato: «Piero, in particular, painted certain prophets on the wall in oil (a method he learned from Andrea del Castagno)».

[19] Vasari, *Lives* (London, 1963, W.m. Gaunt), vol. III, 99.

[20] Vasari, vol. III, 99.

[21] Vasari, vol. III, 118. Peperigni is a light, porous volcanic rock or tuff. See also Giovanni Battista Armenini, *De' veri precetti della pittura*, 1586 (ed. Olszewski, J., 1977), 85: «And among the latter was one Sebastiano Veneziano, who inflicted great injury on art when he abandoned it, for he was capable of producing marvelous paintings such as that of the "Flagellation of Christ at the Column", made in oil on the wall of the church of S. Pietro in Montorio in Rome».

[22] Armenini, 1586, vol. III, 119. Armenini relates that «it was said that Michelangelo refused to paint his "Last Judgement" in this medium, though he was much encouraged by Fra Sebastiano del Piombo, who had persuaded him to prepare the wall for oil paint. It is seen, then, that this advice did not please Michelangelo, who resolved to do the painting in fresco as a method more suitable to a man of his genius, since this method is more enduring as well as a greater challenge to a skillful artist» (Armenini, 1586, vol. III, 191).

[23] Vasari, *Opere*, VII, 667. Around 1540, at the monastery of the Camaldoli near Arezzo, Vasari says «feci esperimento di unire il colorito a oglio con quello (fresco) e riuscimmi assai

have [sic] been whitened, either «a fresco» or otherwise, it must be scraped; or if it be left smooth without whitening but only plastered there must be given to it two or three coats of boiled oil, the process being repeated till the wall cannot drink in more, and when dry it is covered over with the composition or priming spoken of in the last chapter. When this is finished and dry, the artist can trace or draw on it and can finish such work in the same manner as he treats the panel, always having a little varnish mixed with the colors, because if he does this he need not varnish it afterwards. The other method is for the artist to make, either with stucco of marble dust or finely pounded brick, a rough cast that must be smoothed, and to score it with the edge of a trowel, in order that the wall may be left seamed. Afterwards he puts on a coat of linseed oil, and then mixes in a bowl some Greek pitch and resin (mastice) and thick varnish, and when this is boiled it is thrown on to the wall with a big brush, and then spread all over with a builder's trowel that has been heated in the fire. This mixture fills up the scores in the rough cast and makes a very smooth skin over the wall, when dry it is covered with priming or a composition worked in the manner usually adopted for oil, as we have already explained [24].

Significantly, Vasari gives a third recipe for an oil mural in the second edition of his *Lives* (1568), and calls it his «own method»:

> Make the rough cast, over which put the plaster made of lime, pounded brick, and sand, and leave it to dry thoroughly; that done, make a second coating of lime, very finely pounded brick, and the scum from iron works; these three ingredients in equal proportions, bound with white of egg sufficiently beaten and linseed oil, make a very stiff stucco, such as cannot be excelled. But take great care not to neglect the plaster while it is fresh, lest it should crack in many places; indeed it is necessary, if one wishes to keep it good, to be ever about it with the trowel or spatula or spoon, whichever we choose to call it, until it be all evenly spread over the surface in the way it has to remain. Then when this plaster is dry and some priming or composition laid over it, the figures and scenes can be perfectly carried out, as the works in the said palace (Palazzo Vecchio) and many others will clearly demonstrate to everyone [25].

In this last recipe he seems to emphasize the need to develop a plaster support suitable for oil, or in his words, «uniting oil colors with fresco». Between the two editions of his *Lives*, both of which Vasari introduces with technical treatises, he concludes that the layer of hot stucco (made of Greek pitch, mastic resin, and thick varnish) had to be deleted. One wonders to what extent his preoccupation with obtaining a proper preparation layer derived from studying the technical defects of Leonardo's *Last Supper* which Vasari examined in May, 1556; this was just at the time he began his own oil mural projects in the Palazzo Vecchio. He also probably had a chance to examine Leonardo's *Battle of Anghiari* mural, as it was visible until at least 1549 [26]. Vasari relates that Leonardo's use of an overly-thick «glue-like» preparation layer was the undoing of that particular project.

By 1586, Giovanni Battista Armenini could claim in his *De' veri precetti della pittura* that «any important works on panel or canvas are now done in oil» [27]. He had seen the Leonardo *Last Supper* mural, and described the technique as oil on wall. He called the painting a very great miracle, even though «it was half ruined» [28]. By the time Armeni-

acconciamente». He also describes how he painted in oil on the walls of a refrectory at Naples (*Opere*, VII, p. 674).

[24] G.B. Brown, *Vasari on Technique*, New York, 1960, 232. Vasari describes the priming as a «composition of pigments which possess siccative qualities, such as white lead, dryers and earth such as is used for bells». «Bell earths» may refer to the earth used for the moulds in bell casting, or to the clay used for making terracotta bells. Brown (1960, 230-231, n. 13) refers to Baldinucci (*Vocabulario del Disegno*, «Nero di Terra di Campana»), who says that this is a color made out of «a certain scale that forms on moulds for casting bells or cannon, and... it is good with oil, but does not stand in fresco».

[25] Brown, 1960, 234-235.

[26] See the letter written by Doni to his friend Lollio regarding sites to visit in Florence in 1549: «salire nella sala grande a dare una vista a un gruppo di cavalli e di uomini... un pezzo di battaglia di Leonardo da Vinci che vi parrà una cosa miracolosa». For a full treatment of the subject, see C. Pedretti, *Leonardo inedito. Tre saggi*, Florence, 1968.

[27] Armenini, 187.

[28] Armenini, 239. «Among others, I saw in Milan the Refectory of the Brothers of San Domenico in Santa Maria delle Grazie, in which on the left side Leonardo da Vinci painted a Last Supper in oil on the wall. Although even then it was half ruined, even in that state it seemed to me a very great miracle».

[29] Armenini, 191.

[30] In April, 1983, I met with the Soprintendente per i Beni Artistici e Storici of Milan, Professor Carlo Bertelli, and with the conservator in charge of the *Last Supper*, Professoressa Pinin Brambilla Barcilon. Together we inspected the restoration of the mural (the lunette and the right one-fourth of the painting had been cleaned and reintegrated). My examination of the mural in 1975-76 documented an active state of deterioration and a need for conservation treatments. I filed a report with Soprintendente Franco Russoli, who authorized me to remove ten microscopic paint samples from the mural at that time; these were analyzed by Dr. Edward Sayre, Dr. Lambertus van Zelst and Dr. Walter McCrone. This sample research, although by no means complete in addition to complications posed by pollutant materials, may help distinguish between restoration and original passages, as well as provide a basis for further studies of Leonardo's working methods. Hopefully, the results of these analyses will be reconfirmed upon the completion of the current restoration.

[31] That is, from the time that Donato Montorfano completed and signed his fresco in 1495 and when Ludovico il Moro wrote to Marchesino Stampa in 1497 asking that Leonardo complete work on the *Last Supper* (Milano, Archivio di Stato, *Registro ducale*, c. 161).

[32] Antonio de Beatis, «Relazione del viaggio... d'Aragona», 1517-18 (ed. Pasto, 1905): «excellentissima, benché incomincia ad guastarse non so se per la humidità che (trasuda) il muro o per altra inadvertentia».

[33] Giovanni Paolo Lomazzo, *Idea del Tempio della Pittura*, Milano, 1590, 49: «Hora Lionardo fu quello che lasciato l'uso della tempera, passò all'oglio, il quale usava assotigliar con i lambicchi, onde è causa che quasi tutte le opere sue si sono

ni's treatise was published, it appears that the period of great experiments with oil on wall had come to a close:

> Oil paint is customarily used on wood, canvas, and wall, although it has been known for some time that it is ill-suited for use on walls and does not endure long, as seen in the works of good craftsmen [29].

Notes on Several Pigments and Binding Media Used in the Last Supper Mural [30]

Unfortunately, we do not know what materials Leonardo purchased for the *Last Supper* mural project as the documents have been lost. Furthermore, Leonardo's references in his treatises to the materials in his paintings are extremely obscure. We do know that he worked on the *Last Supper* for some two years, from around 1495 to 1497 [31], and that a visitor related that it had begun to deteriorate in just twenty years after completion [32]. Research continues to this day in an attempt to determine the original painting technique and causes of *the mural's extensive deterioration.*

In 1590, Giovanni Paolo Lomazzo wrote in his *Idea del Tempio della Pittura* that a fautly ground layer ruined the *Last Supper:*

> Now Leonardo was the one who left the use of tempera and passed on to oil, which he used to thin down with distillations, whereby it happened that almost all of his works have flaked from the walls, as among others one sees in the council of Florence the admirable battle, and in Milan the supper of Christ in Santa Maria delle Grazie, that are ruined because of the priming that he applied underneath [33].

It is interesting that Lomazzo blames the ground layer of the *Last Supper* for the mural's demise, for Leonardo seems to have combined and followed the recommendations for oil grounds given by Eraclius, Cennini, Alberti and Filarete. The ten samples of the priming layer that were analyzed indicate that a coat of ground limestone ($CaCO_3$) in an organic medium such as a glue was first applied upon the plaster layer of the wall [34] (fig. 2.1-2.10).

Nesquehonite, a white, transparent stone found in veins of serpentine rock of Northern Italy, is intersperced with the limestone [35]. This material was probably added to the limestone to enhance the luminosity of the layer, just as painters added ground marble to their plaster. Yet this particular stone is not a marble type. The discovery of nesquehonite in the ground layer is particularly interesting since Leon Battista Alberti describes the use of a similar material in *De Re Aedificatoria:*

> In the mountain rocks we can find certain veining, very similar to diaphanous alabaster, which is neither a marble type nor a gesso type, although it shares both qualities, of a very friable nature. This material, reduced to a powder and mixed with lime instead of sand, will result in a whiteness and an astonishing brightness, and similar to that of marble [36].

Alberti's description parallels that which is observed in the base layer of the *Last Supper*: a transpa-

1. Sebastiano del Piombo, Flagellation of Christ, oil mural, S. Pietro in Montorio, Rome (Alinari).

spiccate da i muri, si come frà l'altre si vede nel consiglio di Fiorenza la mirabile battaglia, e in Milano la cena di Christo in Santa Maria delle Gratie che sono guaste per l'imprimatura ch'egli diede sotto».

[34] In 1976 Professor Franco Russoli, then Sovrintendente per i Beni Artistici e Storici di Milano, authorized the analysis of ten paint samples from the *Last Supper*. The samples discussed herein are from the same set as that studied and published by MATTEINI and MOLES in *Studies in Conservation*, 24 (1979), 125-133. This paper does not draw from their findings, but is based on two unpublished reports by the Walter C. McCrone Associates, Inc., Chicago and by Dr. Edward V. Sayre, Senior Scientist of the Boston Museum of Fine Arts. Refer to Appendix I for diagrams of samples and binders.

[35] See C. PALACHE, H. BERMAN, and C. FRONDEL, *The System of Mineralogy*, New York, vol. II, 225-227. Edward Sayre reported having located the presence of calcium sulfate (gesso) in the ground layers of several samples, whereas McCrone did not. Identification techniques used were polarized light microscopy, x-ray diffraction and electron microprobe analysis. Nesquehonite is a magnesium carbonate ($MgCO_3$, $3H_2O$), transparent to translucent, colorless to white with a vitreous luster. Although nesquehonite has not typically been associated with works of art, varities of dolomite ($CaCO_3$, $MgCO_3$) and calcium magnesium carbonates ($CaCO_3$, $3MgCO_3$) have been identified (see KÜHN, «Die Pigmente in der Gemälden der Schack-Galerie», *Doerner Institute*, Munich, 1969, and J. RIEDERER, «Recently Identified Egyptian Pigments», *Archaeometry*, 16, pt. 1, 1974, 102-109.

[36] ALBERTI, 500.

2.1. through **2.10.** Diagrams of ten paint cross-sections from the Leonardo Last Supper mural (redrawn by Newton from McCrone, Sayre).

rent material that is neither marble nor gesso but similar to both, mixed with lime instead of sand. This base layer creates a much smoother and more optically reflective surface than the normal plaster layer.

Immediately on top of this layer is a thin stratum of lead white. This appears to be a uniform layer, rather than a local application, as it was detected in most of the samples. This layer would make the wall even smoother for painting and increase the capacity for reflecting light through the various paint layers. Leonardo himself gives the reason for using a bright, white ground:

> For those colors that you wish to be beautiful, first always prepare a very pure, white ground. This I say with regard to transparent colors, for a bright ground is not an advantage to those colors which are not transparent [37].

The white priming assumes the color of the overlying paint layers while intensifying the hue, according to Leonardo:

> Black will look most intense against the whitest background... Every opaque and colorless body assumes the hue of the color reflected on it; as happens with a white wall [38].

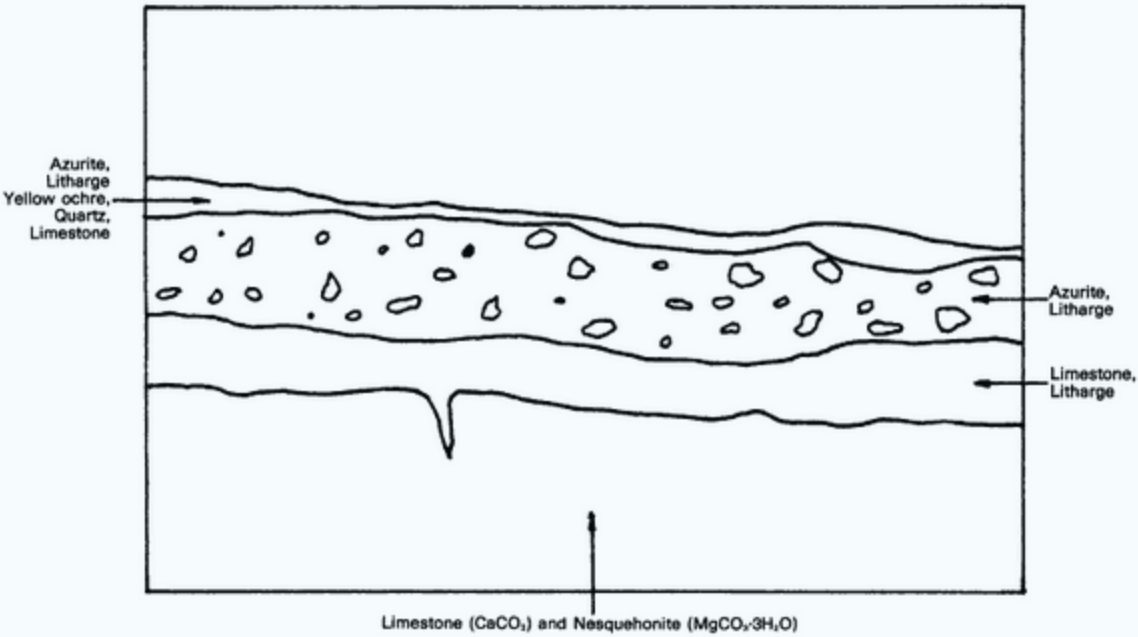
We may conclude therefore that the primary function of the layers of limestone, nesquehonite and lead white was to provide a smooth, optically reflective priming layer for a generally transparent paint film.

Lomazzo may be partially correct in blaming the priming layer for the mural's demise. The basic problem however is built into the wall, since the elevated water table beneath Santa Maria delle Grazie has fostered moisture intrusion into the wall by capillary action. Yet the Montorfano fresco opposite the *Last Supper* is in a relatively good state of preservation. The explanation, at least in part, is that true fresco allows the wall to «breathe» while the mixture of limestone, lead white, glue and oil in the *Last Supper* block the migration of moisture and soluble salts whithin the wall [39]. A

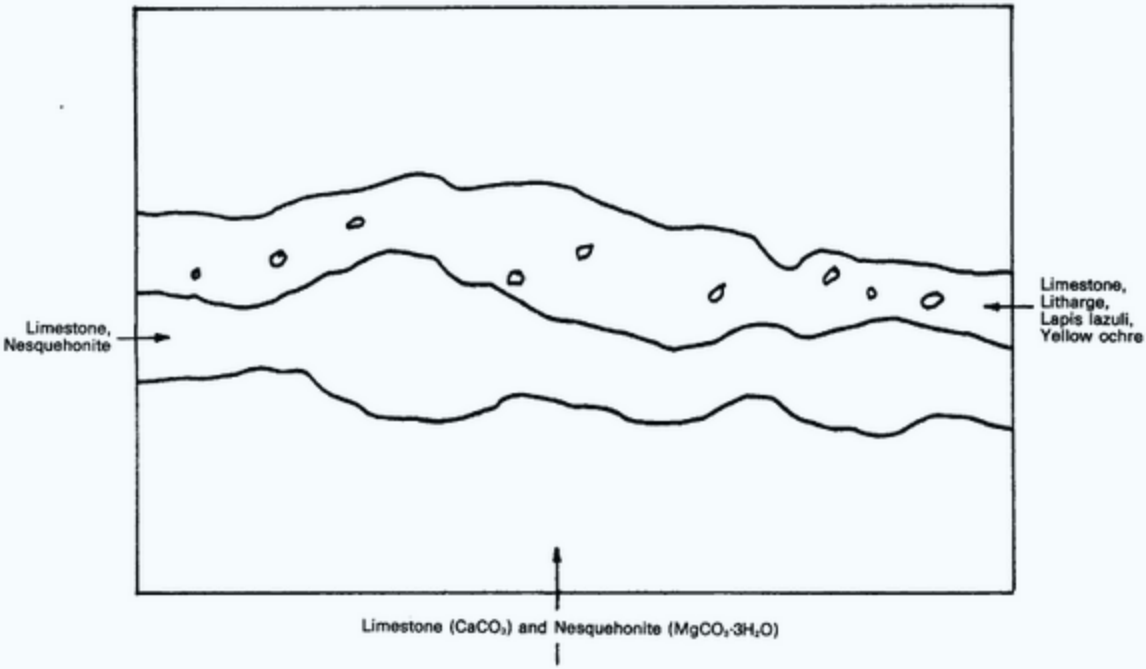
[37] P. McMahon, *Leonardo da Vinci's Treatise on Painting*, Princeton 1956, 85.

[38] McMahon, 1956, 227-228.

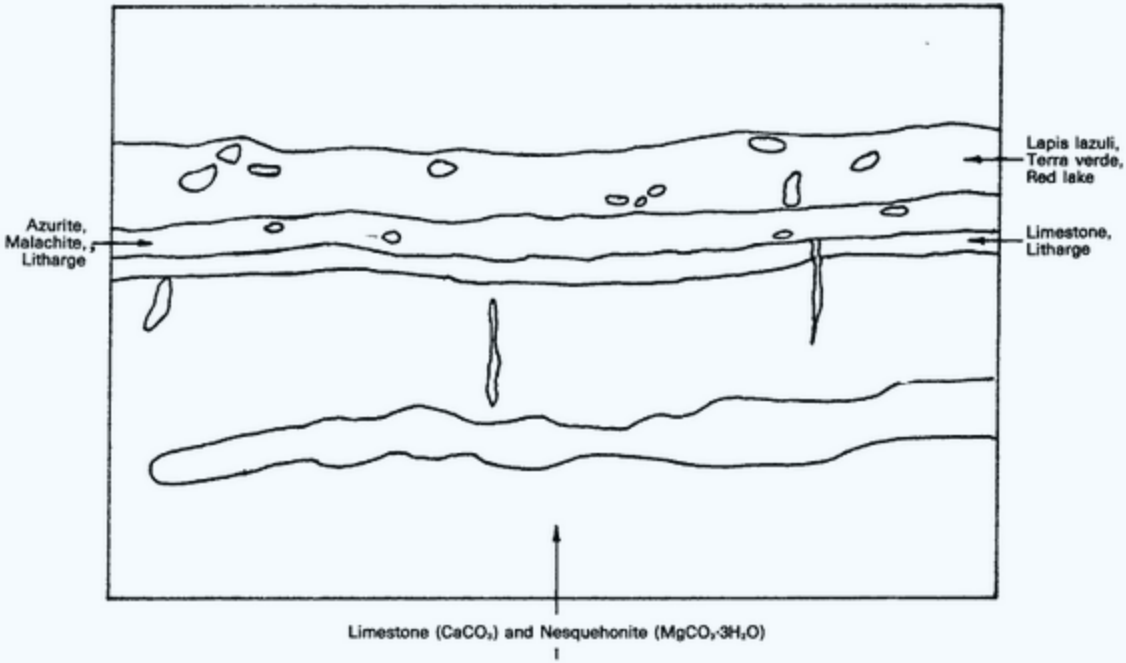
[39] This situation is analogous to the breakdown of modern building cement (Portland), since it blocks salt and moisture migration. In contrast, Roman mortar has fared relatively well (e.g., the lime mortar that supports the Coliseum) as it allows the passage of soluble salts. See *Newsletter*, Society of Arch. Historians, XXVI (April 1982), 2, 6. Leonardo may have used lead white in the ground as a barrier to moisture intrusion, as he was aware that moisture causes structural deterioration in walls (see A. Richter, *The Literary Works*, London, 1939, vol. II, 60). Cennini noted that «it is sometimes necessary to take steps for jobs to be done on damp walls» (p. 119), in other words, the artist could not always choose the surface for his mural. Cennini prescribes various methods for waterproofing a wall, among others the application of boiled linseed oil, hot pitch or hot varnish (pp. 120-121). Eastlake, 1960, vol. II, 62 relates that one of the reasons that the oil on wall technique was developed in the North was to waterproof walls and as a reaction to the deterioration of fresco paintings.



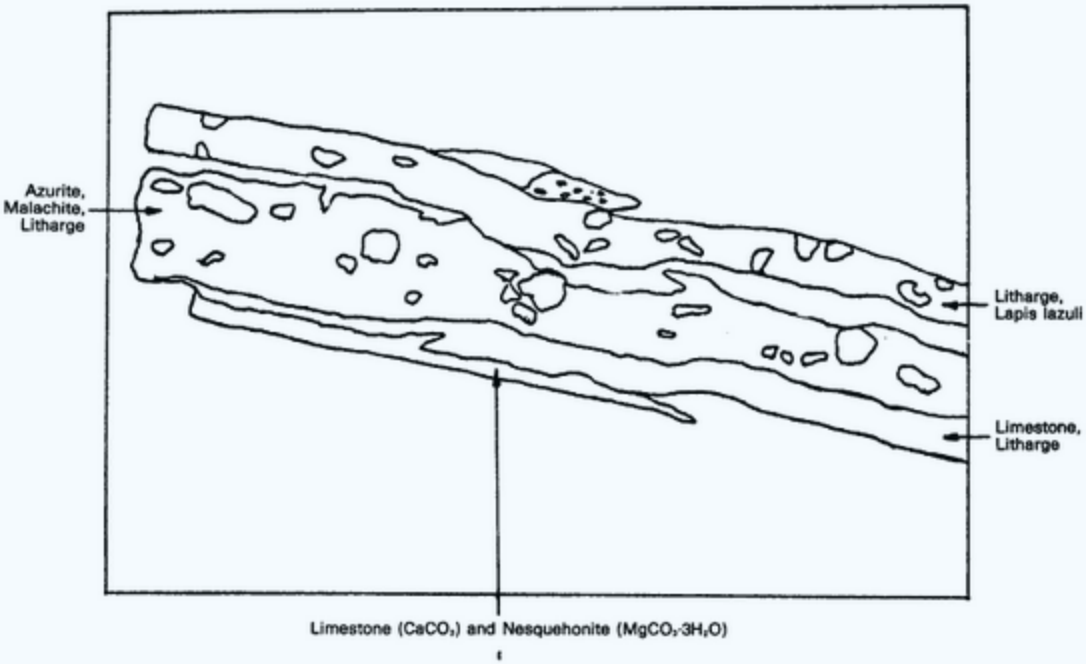
2.1. Section of the tablecloth with blue decoration, immediately below Mattheus (magnified 160x).



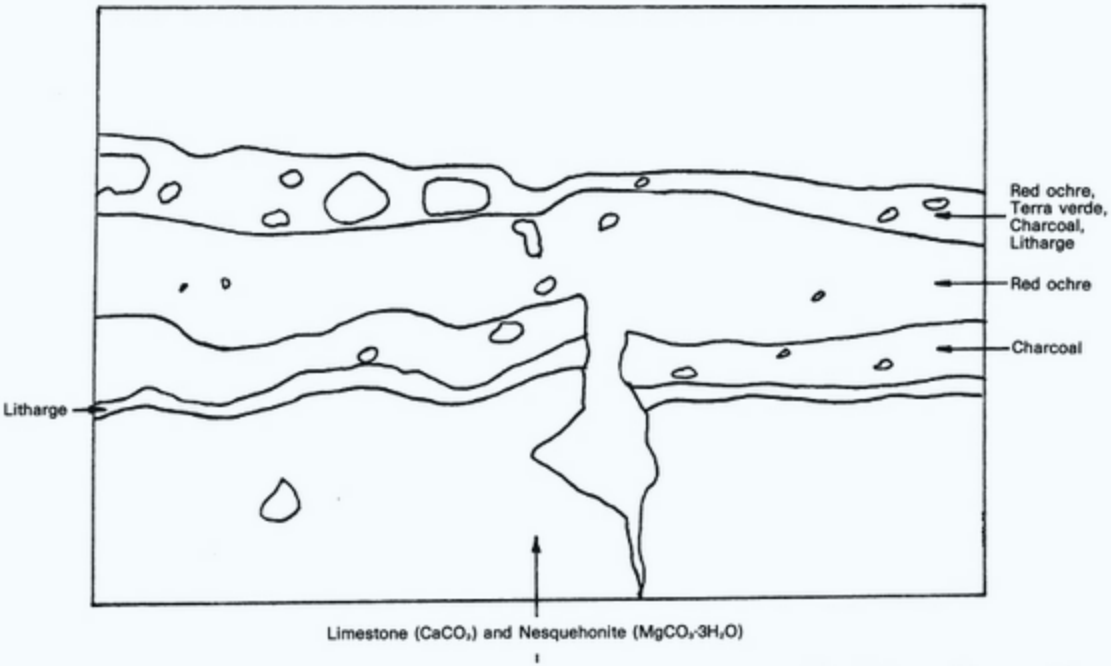
2.2. Section of the tablecloth, apparently without blue decoration. This sample was removed from an area immediately below sample 2.1, but in an area where no shellac was applied (1950) (magnified 160x).



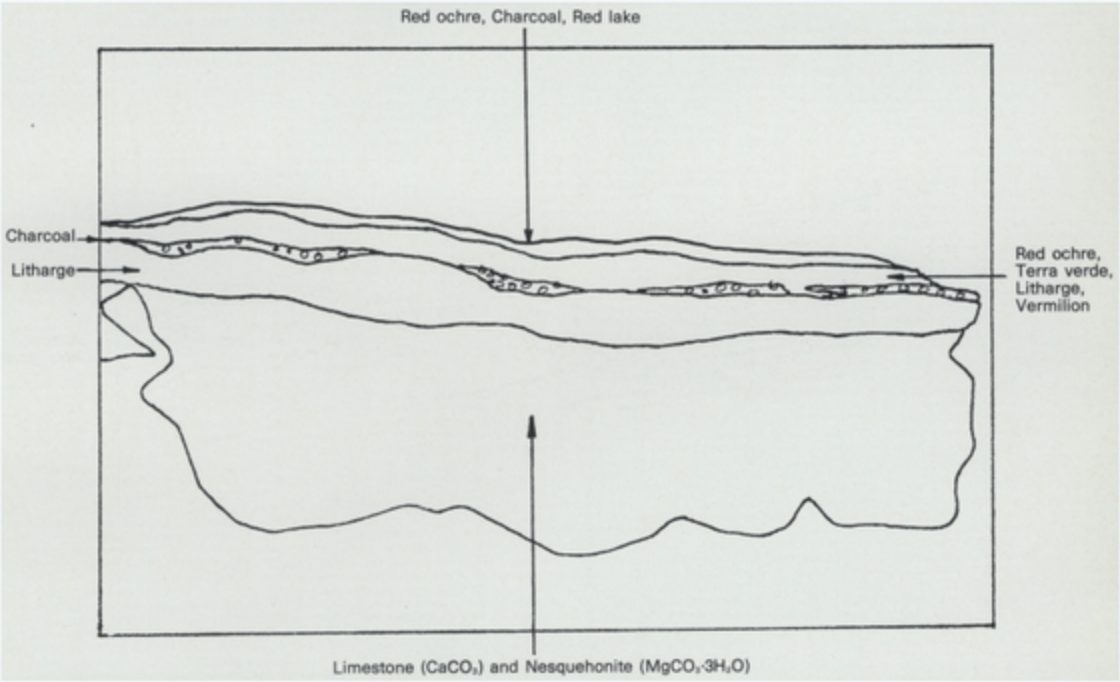
2.3. Section of Christ's mantle, composed of a dark blue overpaint on a lighter blue original (magnified 160x).



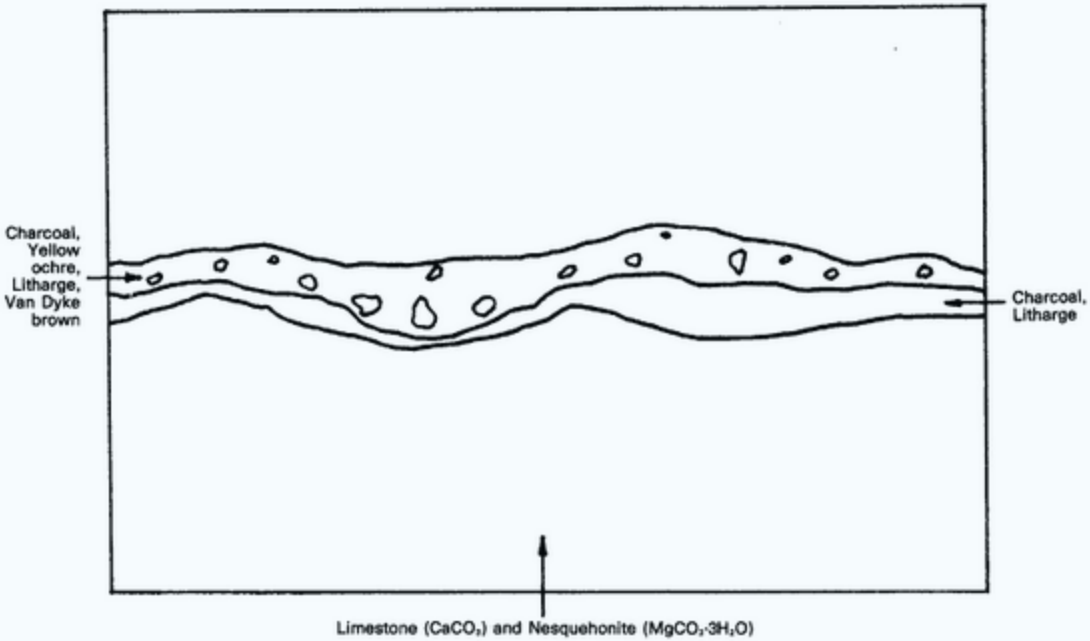
2.4. Section of sky, removed from the viewer's upper left area of central window (magnified 160x).



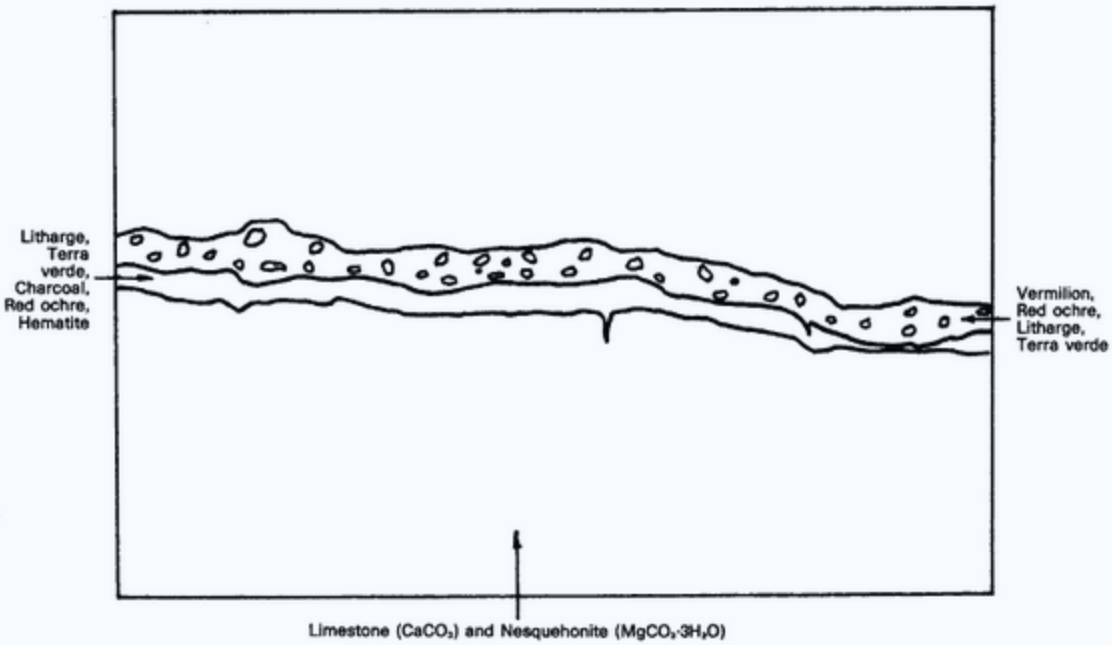
2.5. Section removed from panel of wall architecture on the viewer's left of Christ. Sample composed of a dark brown, shiny overpaint with some traces of a light red (possibly original) pigment underneath (magnified 160x).



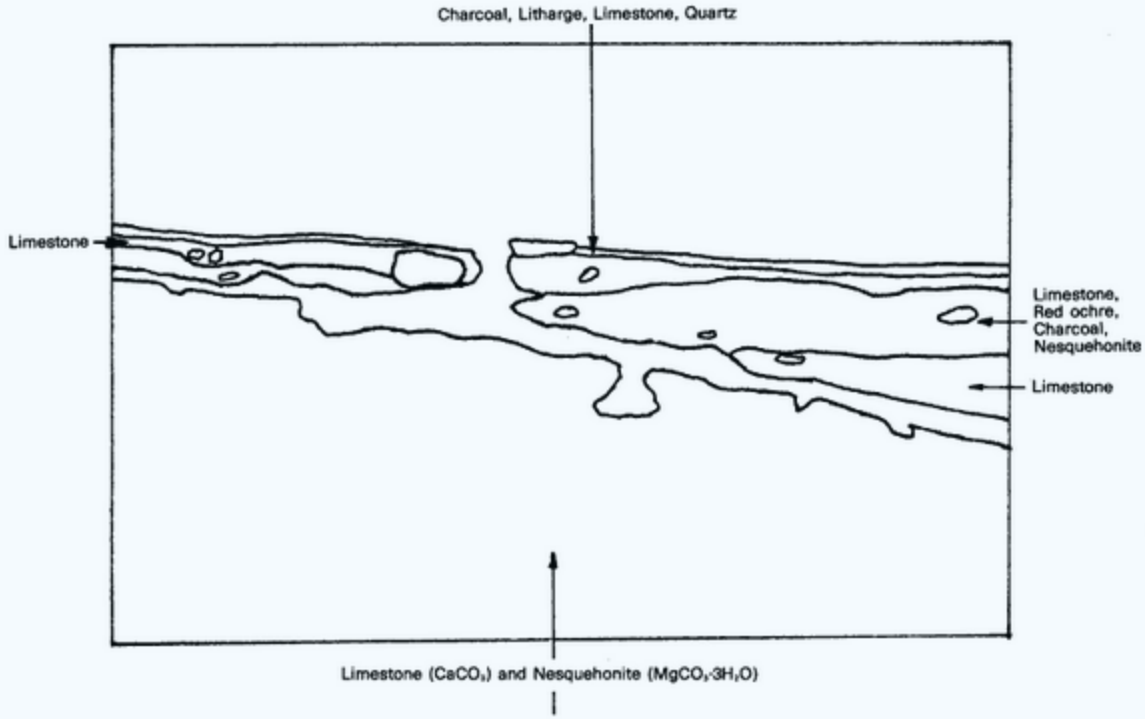
2.6. Section removed from Christ's right sleeve, just before his hand. The sample is composed of a bright-red original layer, covered by some darker red overpaint (magnified 160x).



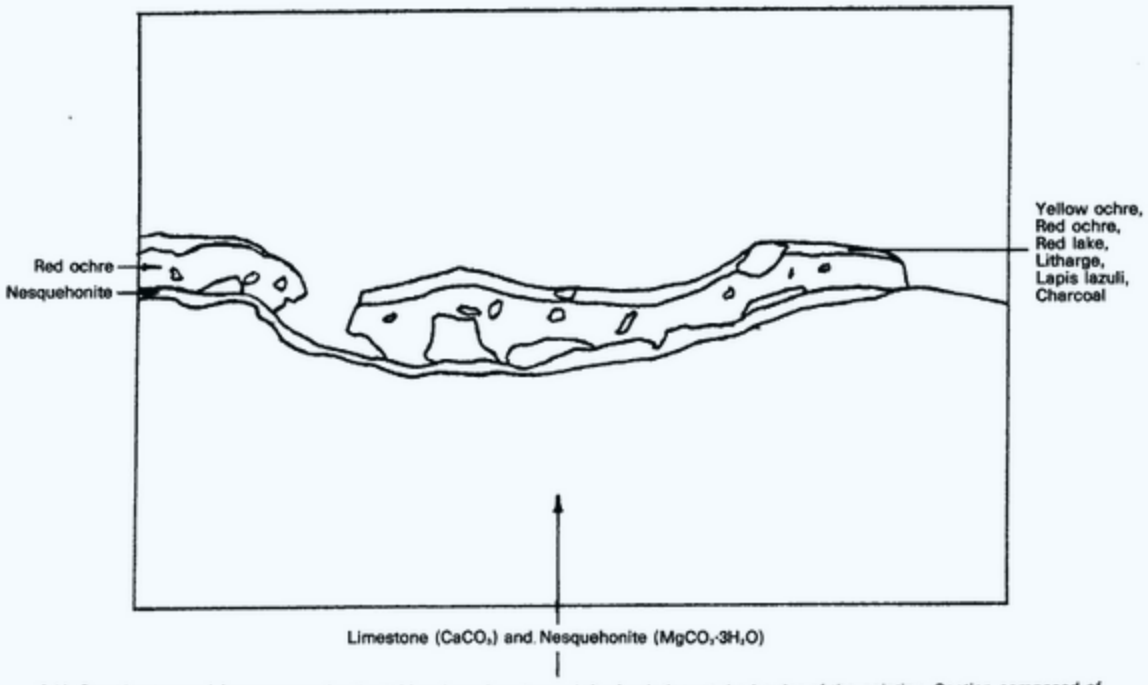
2.7. Section removed from the table area immediately below Christ's right hand, composed of grey and white pigments, preparation and intonaco (magnified 160x).



2.8. Section removed from Peter's right sleeve, just before his hand holding the knife. Sample composed of brown pigment and preparation layer (magnified 160x).



2.9. Section removed from the tablecloth under the right elbow of Judas, composed of a dark grey pigment (believed to be original) on two layers of off-white preparation (magnified 160x).



2.10. Sample removed from area under the table, viewer's extreme left of painting, at the border of the painting. Section composed of brown overpaint, traces of red underneath, and yellow preparation layer (magnified 160x).

tension is set up and the paint film eventually gives way in the form of flakes. An examination of the paint cross sections suggests a tension between support and paint layer, with cracks in the ground meeting fissures in the paint layer at right angles. Such a tension clearly leads to flaking paint.

In general, the pigments identified in the ten samples are frequently found in mural paintings of the 15th century. Notable exceptions are lead white, vermilion, and red lake which muralists generally avoided due to their unstable qualities. Cennino Cennini, for example, advised against their use on wall:

> But bear in mind that it is not its [vermilion] nature to be exposed to the air, but it stands up better on panel than on the wall; because, in the course of time, from exposure to the air, it turns black when it is used and laid on the wall [40].
> [White lead] is even used on walls, but avoid it as much as you can, for in the course of time it turns black [41].
> Red lake is good on panel; and it is also used on the wall with a tempera; but the air is its undoing [42].

Leonardo was probably aware of the dangers of using these pigments on wall. For example, he was preoccupied with the possibility of verdigris turning black:

> Verdigris with aloes, or gall or turmeric, makes a fine green, and so it does with saffron or burnt orpiment; but I doubt whether in a short time they will notturn black [43].

Despite the damp wall, the lead white in the *Last Supper* samples has not turned black, for reasons which are not yet clear.

Paint layers of varying hue are superimposed oner the white ground. There appears to be no homogeneous base tone (other than the white ground); instead localized tones are built up according to the desired effect [44]. In several samples, a layer of lapis lazuli, mixed with lead white, has been applied over a layer of the less costly azurite blue. This follows the tradition of Italian painting, as described by Cennini:

> If you want to put ultramarine blue on a ground or on a drapery... apply two or three coats of it over azurite [45].

But whereas Cennini describes preparing the ground in a mixture of black and sinoper for azurite or ultramarine, Leonardo has used the pure white luminous ground.

Some samples have a glaze as an intermediate or final layer (e.g. transparent pigments suspended in abundant transparent medium). In the third sample, a dark blue is created by the application of azurite, malachite and litharge; this has as a final glaze a mixture of lapis lazuli, green earth and a red lake. Glazes can be used to reduce the intensity of certain opaque pigments, as Leonardo noted: «Lac and verdigris make a good shadow for blue in oil painting» [46].

A pattern of «toning down» begins to emerge, whereby the brighter component of the final desired hue lies just beneath the surface. For example, in the fifth sample we find a layer of charcoal black upon the lead white. Over this is a bright layer of red ocher, with an uppermost stratum of brown composed of red ocher, terra verde, charcoal and litharge. So we find a process of contrasting light with dark, toning up and then toning down. In Christ's red sleeve, a deep red tonality is achieved by layering contrasting hues. A layer of charcoal black lies on top of the lead white priming. Over this is a layer of bright red body color (red ocher, terra verde, lead white and vermilion) which is toned down by a uppermost layer of red ocher and charcoal. Traces of a red lake glaze were detected in the upper layers as well [47]. This type of layering is similar to sample eight, and parallels Leonardo's own recipe for building up a red layer:

> To make a fine red take cinnabar [e.g., vermilion] or red chalk or burnt ocher for the dark shadows... and for the lights pure vermilion, and then glaze with fine lake [48].

In sample nine, where gray is the final hue, the section begins with the white ground, then a layer of off-white, then gray, then off-white, and finally gray. Quartz, limestone and nesquehonite are mixed throughout the various strata thereby uniting them and creating a translucent white. In sample ten, the section is composed of the white ground, a translucent white, a red layer (red ocher), and a final brown composed of contrasting dark and

[40] Cennini, 24. Vermilion has been identified on Pomepilan and Byzantine wall paintings: see Gettens, Feller, Chase, *Studies in Conservation*, vol. 17, 2, May 1972, 45-69.

[41] Cennini, 34. Note that Filarete recommends using lead white in linseed oil on wall (Eastlake, 1960, vol. II, 66).

[42] Cennini, 27.

[43] Richter, 1939, vol. I, 361.

[44] This is in keeping with the findings of Magdeleine Hours, who examined several of Leonardo's paintings in the Louvre. See M. Hours, «Analisi delle Pitture di Leonardo da Vinci Eseguita al Laboratorio del Museo del Louvre», in *Leonardo Saggi e Ricerche*, 1952, 531.

[45] Cennini, 55.

[46] Richter, vol. I, 361: «Lacca e verderame fa bon obra allo azzurro a olio».

[47] Matteini and Moles, 1979, 129.

[48] Richter, 1939, col. I, 360.

[49] McMahon, 1956, 81.

[50] McMahon, 1956, 83.

[51] McMahon, 1956, 83.

[52] McMahon, 1956, 84.

light, opaque and transparent: e.g., lead white and charcoal black, red lake and red ocher with natural ultramarine. A little yellow ocher completes the brown tonality.

There may in fact be a correlation between the stratification of light and dark, opaque and transparent pigments and certain aspects of Leonardo's color theory. For example, in his chapter on «Harmony and Contrast» he writes:

> If you wish quickly to see all the varieties of composite colors, take pieces of colored glass and through them look at all the colors of the countryside which you can see beyond them. There you will see that all the colors of objects which are seen beyond the glass, are mixed with the color of that glass, and you will see which color is strengthened or impaired by such a mixture [47].

Leonardo applies this theory of various combinations of colored glass to the layering of transparent pigments:

> When a transparent color is placed on another color, it becomes changed by it, there is composed a mixed color, different from both the simple ones that compose it. This is seen in smoke coming out of chimneys which, when it is in contrast to the black of the chimney, appears blue; and when it rises, in contrast with the blue of the air, it appears gray or reddish. So also scarlet laid upon blue makes violet, and when blue is put on yellow it makes green, saffron on white makes yellow. Bright color upon dark makes a blue the more excellent as the bright and the dark color are themselves the more excellent [48].

Hence the contrasting tonalities are superimposed to achieve a new, brighter composite color since «among colors of equal perfection the one which will appear most excellent is that which is seen with its direct contrast» [51]. The concept of contrast is linked to that of harmony for the goal of superimposing colors is to achieve a pleasing final hue. The basic principal for putting colors together so that each makes the other attractive is derived from nature:

> If you wish the proximity of one color to make another which it borders attractive, observe the rule which is seen in the rays of the sun that compose the rainbow... [52].

An analysis of the binding media found in the pigment layers of the *Last Supper* is complicated by the various oils, glues and gums which were applied to the paint surface during past restorations. Hence it is not always clear what is original and what is a subsequent addition. Furthermore, initial research indicates that more than one type of binding medium was used in the application of the ground and paint layers.

The ten pigment samples were examined, in part, for the presence of glue, egg tempera and oil media. The selective staining method of Johnson and Packard was used [53], whereby paint layers that accepted the stain for oil but not for protein indicated the presence of oil. Those that stained for protein and a moderately positive stain for oil indicated egg tempera. Those that stained for protein but not for oil signified the presence of glue. In addition, emulsions made by combining egg with oil can be identified by this method. Layers that are composed of neither oil, egg or glue (e.g., resins and gums) will not stain at all.

This staining technique indicates that the white ground layers are suspended in a type of glue medium. Glue was detected in the priming layers in six of the ten samples. Cennino Cennini recommends applying glue to a wall when preparing it for oil [54]. We find references in Leonardo's writings to animal, fish and rice glues, as well as gum arabic [55]. He also mentions a type of plaster mixed with glue: «gesso, sawdust, clipping and glue make good plaster» [56].

An oil type binding medium was detected in pigment layers of eight of the ten samples. The presence of oil within the paint layers was by no means uniform in the ten samples, but it does appear to represent the predominant painting medium. Leonardo gives a recipe for painting in oil: «To make good oil for painting. One part of oil, one of the first turpentine and one of the second» [57]. He describes methods of preparing various types of oil including linseed, walnut and mustard [58]. His notations include lists of pigments together with «oil for painting» [59]. Lomazzo relates that Leonardo painted the *Last Supper* in oil thinned with distillations [60]. Armenini also describes

[53] JOHNSON and PACKARD, 1971. The stains used in Sayre's examination for protein identification were Coomassie Blue R 250 and Ponceau S; Sudan Black B was used for oils. McCrone's ion microprobe scan of sample 6 indicated the presence of oil.

[54] CENNINI, 56: «Poi, o vuoi chon ispugna, o vuoi col pennello morbido et mozetto, darne (la colla) una volta per tutto il campo che ai allavorare; ellascialo asciugare almen per un dì».

[55] For references to various oils, glues and varnishes see RETI, L., «Gli Studi sulla Chimica di Leonardo», in *Leonardo Saggi e Ricerche*, 1952, 49-56. See also C. PEDRETTI, *The Literary Works of Leonardo da Vinci*, 1977, vol. I, 359-68; and RICHTER, 1939, vol. I, 359-366.

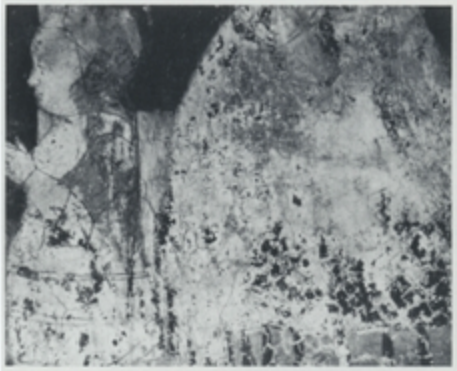
[56] PEDRETTI, 1977, vol. II, 21: «anchora giesso / segature e cima / tura e colla fa / bono stucho».

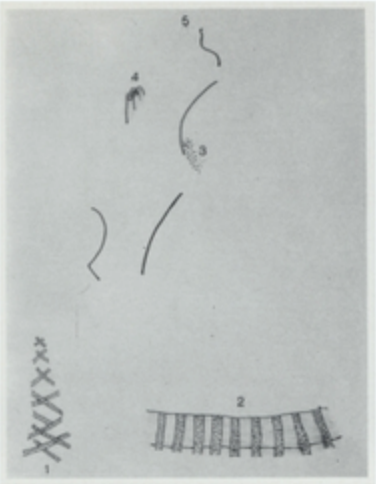
[57] RICHTER, 1939, vol. I, 360: «Per fare olio buono a dipingere, Una parte d'olio una di prima di trementina e una di seconda».

[58] RETI, 1952, 49-56.

[59] RICHTER, 1939, vol. I, 382.

[60] LOMAZZO, 49: «passò all'oglio, il quale usava assotigliar con i lambicchi».





		3	9.2	9.3	10
4	5	6	11	12	13
7	8	9.1			

3. Donato di Montorfano, The Crucifixion of Christ, overall, fresco, 1495, Santa Maria delle Grazie (Alinari) ■ **4.** Detail photo of Ludovico il Moro and son Massimiliano in Montorfano mural (Newton) ■ **5.** Detail photo of Beatrice d'Este and son Francesco in Montorfano mural (Newton) ■ **6.** Detail photo of Beatrice d'Este and son Francesco in Montorfano mural (Newton) ■ **7.** Diagram illustrating the sequence of application of the various giornate in figure 5. Note that the forms of Francesco and Beatrice were applied before the plastering of the surrounding giornate (Tintori and Newton) ■ **8.** Diagram of a tracing of the lines incised into the dry plaster in the area of Beatrice and Francesco (Tintori and Newton) ■ **9.1.** Diagram of incised lines superimposed onto diagram of giornate and Montorfano composition, showing a shift in the placement of the forms (drawing by Newton) ■ **9.2.** Diagram of the areas of existing pigmentation on the reworked forms of Beatrice d'Este and Francesco: 1) Bands of gold leaf and bright green form a sash for the incised lines indicating a new form for Francesco; 2) gold leaf, brown pigment and a bright green comprise the lower edge of Beatrice's dress; 3) area of a bright blue pigment; 4) fingers enlarged with white and flesh tones; 5) chin lifted with a dark outline (drawing by Newton) ■ **9.3.** Diagram of incised lines superimposed onto diagrams of giornate as well as the areas of secondary paint application (Newton) ■ **10.** Diagram of the nature of folds in drapery by Leonardo, Paris, National Library (Richter, Plate XXVIII, 6, 390) ■ **11.** Drawing illustrating folds in drapery by Leonardo, Windsor Castle, 12705 (Richter Plate XXVIII, 7, 391) ■ **12.** Drapery study by Leonardo, Corsini Gallery, Rome ■ **13.** Photograph of scaffolding being moved to west wall of the Salone dei Cinquecento, Palazzo Vecchio, Florence, in 1977 (Newton).

the use of an oil medium in the mural [61].

The painting does not appear, however, to be a simple oil mural on a glue ground. In several paint samples the binding media alternates from oil to tempera to oil. Pigment layers in four samples have some tempera binding medium. In three samples (1, 3, 8), the primary pigment layer is suspended in an oil medium; the mid region of the cross section stains positively for tempera, and the outermost pigment layer is in an oil medium.

It is possible that some of the tempera or oil layers may represent old restorations. Yet it was common to superimpose tempera and oil in Italian painting of this period. For although the 16th century was a time of intense experimentation, recent studies show that oil was only gradually substituted for egg tempera. One often finds a complex use of both oil and egg tempera in paintings of the second half of the 16th century [62]. The media in a single painting may vary layer by layer, with tempera and oil superimposed in multi-layered paint strata. And in Leonardo's writings, in addition to the references to oil, we find egg albumen mentioned numerous times [63]. In a notation to himself he wrote «learn to work flesh colors in tempera» [64].

Further research is necessary to understand the reasons for using egg tempera in conjunction with an oil medium. There does seem to be a correllation, however, between the use of oil and transparent pigments. In four samples (3, 8, 6, 10), the outermost paint layer contains a transparent lake pigment in an oil binder. Samples that have a tempera layer sandwiched between oil layers (1, 3, 8), are composed of paint layers of contrasting hue with the tempera mid region made up of opaque colors mixed together (e.g., earth colors, lead white). Tempera may have been used to build up effects of body, while oil may be associated with certain transparent effects such as glazing or toning down a color.

The Portaits of Beatrice d'Este and Her Son Francesco in Santa Maria delle Grazie

Giovanni Donato di Montorfano painted a large fresco depicting the *Crucifixion of Christ* on the wall facing the Leonardo *Last Supper* in 1495 (fig. 3). The figures of Ludovico il Moro and his eldest son Massimiliano are in the lower left corner of the composition, and Beatrice d'Este and son Francesco are depicted in the lower right (fig. 4-6). Although the major part of the fresco is in a relatively good state of preservation, the pigment layers associated with these four figures have almost completely flaked away leaving bare plaster. This in itself is indicative of a secco rather than a fresco technique. Further examination of the figures of Beatrice d'Este and her son indicates that these two forms were reworked after Montorfano completed his fresco of the crucifixion.

The advanced state of deterioration of the portraits makes their attribution a complicated matter. The earliest reference that suggests a link between Leonardo and the portraits comes from Ludovico il Moro himself who, in a letter to Marchesino Stampa of June 29, 1497 says «solicit Leonardo the Florentine to finish the work he began on the refectory of the Grazie, then to attend to the other facade of that refectory» [65]. Both Vasari (1568) and Lomazzo (1584) attribute the figures to Leonardo, when they were obviously in a far better state of preservation than they are today [66].

Examination of Beatrice d'Este and Francesco shows that they were included originally in the Montorfano fresco. This is clear in reference to composition since the left hand of the figure behind Beatrice d'Este rests on her shoulder. It is also clear from an examination of the plaster that Beatrice and Francesco comprise a giornata; the giornate of the surrounding figures were added subsequently as evidenced by the overlapped edges of the plaster joins (fig. 7). There are traces of a «spolvero» design on the hands and head of Francesco. These charcoal dots are still visible because they were applied onto the wet plaster and became incorporated into the surface just as carbonation of wet plaster effects a paint layer in true fresco. Hence the «spolvero» represent the transfer of Montorfano's original design from cartoon onto wall.

No clear indication remains whether Montorfano ever painted in these figures with color in a fresco technique. What we see today is essentially bare plaster with the outlines of the figures painted in a brown pigment which is more or less incorporated into the plaster. These painted outlines correspond to the boundaries of the figures as indi-

[61] Armenini, 239

[62] Johnson and Packard, 1971, 157.

[63] Reti, 1952, 50.

[64] Richter, 1939, vol. II, 349.

[65] Richter, 1939, vol. II, 349: «de solecitare Leonardo fior(enti)no, perché finischa l'opera del Refettorio delle Gratie principata, per attendere poi ad altra fazada d'esso refitorio...».

[66] Vasari relates: «Nel medesimo refettorio, mentre che lavorava il Cenacolo, nella (parete di) testa dove è una Passione di maniera vecchia, (Leonardo) ritrasse il detto Ludovico con Massimiliano suo primogenito e dall'altra parte la duchessa Beatrice con Francesco, altro suo figliuolo, che poi furono ambedue duchi di Milano, che sono ritratti divinamente».

cated by the original giornate; this is seen, for example, in the outline of Francesco's face, hands and dress.

The proof that these two figures were reworked at a later date is provided by many fine lines that were incised into the dry plaster with a sharp instrument (fig. 8). It is clear that the plaster was dry when the lines were added as their furrows are rough and uneven; if the plaster had been wet the edges of the lines would be relatively smooth. By placing a sheet of transparent paper against the wall, Leonetto Tintori and I were able to make a composite drawing of these incised lines. As the figures were reworked, the boy is shifted slightly towards the center of the composition so that he is no longer in direct contact with his mother (fig. 9.1-9.3). The dress of Beatrice is heavily reworked. In both dresses, the lines seem to carve out a three dimensional space for the forms with their emphasis on the roundness of the dress as it meets the floor.

Leonardo wrote in his *Treatise on Painting* on the nature of folds in drapery (fig. 10-11), and was clearly interested in the dynamics and appearance of drapery bound to a figure and that of drapery allowed to fold into its natural state (fig. 12):

> That part of a fold which is farthest from the ends where it is confined will fall most nearly in its natural form.
> Everything by nature tends to remain at rest. Drapery, being of equal density and thickness on its wrong side and on its right, has a tendency to lie flat; therefore when you give it a fold or plait forcing it out of its flatness, note well the result of the constraint in the part where it is most confined; and the part which is farthest from this constraint you will see relapses most into the natural state; that is to say, lies free and flowing [47].

The lines incised in Beatrice's dress seem to illustrate at least part of this observation; the folds that are constrained by her arm and shoulder are not free but are organized into a rigid pattern of parallel lines. The folds that are farthest from the constraint of the arms and shoulder and allowed to lay on the floor fall into a natural, disorganized pattern of rest.

An explanation why an artist would incise lines into dry plaster rather than using paint or chalk is to be able to follow the drawing with various layers of paint; in other words, the incised lines may have allowed the artist to more clearly distinguish between the Montorfano and altered composition. Cennino Cennini wrote that to paint a blue robe for the Virgin the artist should «first scratch in the plan of the folds with some little pointed iron, or with a needle» [48]. This is also true for gilding work, where the gold leaf might otherwise hide the underdrawing.

> When you have got your whole ancona drawn in, take a needle mounted in a little stick; and scratch over the outlines of the figures against the grounds which you have to gild, and the ornaments which are to be made for the figures, and any special draperies which are to be made of cloth of gold [49].

In fact there are traces of gold leaf and bits of bright pigments in the area of the reworked forms. A sash in Francesco's dress is criss-crossed with bands of gold leaf. This sash is also colored with brown lines and a bright green pigment. At the base of Beatrice's dress are rectangular sections of gold leaf. Tassles are painted in a bright green, with brown and black stripes. A bright blue pigment was noted in the area of Beatrice's chest; her hands were enlarged, and the tips of the fingers are indicated by a white paint. In addition, the position of her head appears to have been altered. Her chin was lifted up so that she would look towards the Christ figure in the central portion of the composition.

We may conclude that Montorfano created the original design of Beatrice d'Este and Francesco, although it is unclear whether he ever actually colored in the forms. His composition was altered when the plaster had dried by someone using a sharp instrument. These incised figures were painted in vivid colors using a secco technique. The reproduction of these incised lines may help future students regarding the authorship of the altered forms.

Notes on The Battle of Anghiari

Several documents exist regarding materials purchased for the *Battle of Anghiari* mural painting [50]. As in the *Last Supper*, it appears that this painting was to have been a predominantly oil type mural painting.

The history of the painting and various accounts of technical difficulties that Leonardo encountered have been adequately described elsewhe-

Lomazzo writes: «Nel refettorio delle Grazie, di mano del Vinci si vede anco il ritratto di Ludovico e Beatrice, tutti e due ginocchioni, con figli davanti». A lengthy treatment of this subject is to be found in L. Beltrami, «Donato Montorfano e la collaborazione di Leonardo nella "Crocifissione" del Refettorio di S. Maria delle Grazie», *Rassegna d'Arte Antica e Moderna*, July 1921, 217-232. See also De Rinaldis, *Storia dell'opera pittorica di Leonardo da Vinci*, 1926, 139 ff.; Suida, *Leonardo und sein Kreis*, 1929, 96.

[47] Richter, 1939, vol. I, 269.

[48] Cennini, 54.

[49] Cennini, 76.

[50] Cf. K. Frey, in *Jahrbuch der Koniglich Preusszischen Kunstsammlungen*, 1900, 129 ff. and G. Gaye, *Carteggio inedito*, 1840, 87-90.

re [71]. Whatever the fate of the project, we know that Leonardo worked on the mural for a full year, from June 1505 to the end of May 1506, with at least two assistants [72].

The Anonimo Gaddiano relates that the *Battle of Anghiari* was painted with varnish, and Paolo Giovio said that Leonardo used nut oil [73]. Indeed, records show that both linseed and walnut oil were purchased for the project. A considerable quantity of gesso from Volterra is recorded in the documents. Cennini recommends using this substance mixed with an animal glue as the ground layer on a panel painting [74]. Greek pitch was provided for; Vitruvius recommends using it in order to waterproof a wall [75]. Vasari relates that Sebastiano del Piombo used greek pitch, mixed with mastic varnish and lime, as a priming for his oil mural in S. Pietro in Montorio [76]. Other materials recorded for this project include a considerable quantity of lead white, caustic soda, gold leaf, various unnamed colors and a quantity of Venetian sponge [77]. Raffaello d'Antonio di Baigio and Ferrando Spagnolo were paid for assisting in the painting of the mural. Tomaso di Giovanni Masini was employed to grind the colors [78].

Research in the Palazzo Vecchio culminated in 1977 when traces of pigments suspended in an oil medium were discovered beneath portions of Giorgio Vasari's frescoes on the west wall of the Salone dei Cinquecento [79] (fig. 13). Examination of various samples indicates that the preparation layer is composed of limestone and charcoal in oil. The paint layer is comprised of from one to five different paint strata. In one instance, for example, the layers alternate from red to white to red to white. Evidence of a charcoal sketch was detected in several samples in the uppermost layer. Over ten different pigments were identified in some fifteen samples; these included charcoal, yellow ocher, hematite, other iron earths, red lead, terra verde, quartz, burnt sienna, ultramarine, azurite and smalt [80].

It is clear that this painted plaster layer has no relation to the Vasari murals due to conflicting dimensions, use of an oil medium and pigments that were not intended to be covered over with another plaster layer. Evidence of layering contrasting colors to achieve luminous effects and the possible presence of a charcoal sketch suggests the beginning of an oil mural.

The Sovrintendenza per i beni artistici e storici has conducted new research regarding the possible presence of the *Battle of Anghiari* during the past four years, and we await the results of their efforts with anticipation. Through their investigation, and with future collaboration between art historians and conservators, the history of Leonardo's last oil mural project may be finally uncovered.

[71] PEDRETTI, 1968; J. WILDE, «The Hall of the Great Council of Florence», *Journal of the Warbourg and Courtauld Institute*, VIII (1944), 65-81.

[72] GAYE, 1840, 89.

[73] EASTLAKE, 1960, vol. II, 115.

[74] CENNINI, 70: «giesso grosso, cioe volteriano».

[75] MORGAN, M.H., *Vitruvius The Ten Books on Architecture*, Cambridge 1914, 209.

[76] Refer to note 21.

[77] GAYE, 1840, 89.

[78] GAYE, 1840, 89-90.

[79] H.T. NEWTON, and J.R. SPENCER, «Appunti sulla "Battaglia d'Anghiari" di Leonardo», *Prospettiva*, 19, ottobre 1979, 98-101; and «On the Location of Leonardo's "Battle of Anghiari"», *The Art Bulletin*, March 1982, 45-52.

[80] Unpublished report by the Walter C. McCrone Associates, Inc., Chicago. Dr. John Christensen, representative of the Armand Hammer Foundation, reported that a copper green pigment had been identified as well.